REMARKS

I. Introduction

In response to the Office Action dated August 14, 2007, claims 1, 10 and 11 have been amended, claims 2-4 have been cancelled, and claims 12-16 have been added. Claims 1 and 5-16 are in the application. Re-examination and re-consideration of the application, as amended, is requested.

II. New Claims

Applicants' attorney notes that support for claim 12 can be found in Applicants' specification on p. 7, lines 26-27; support for claims 13, 14 and 16 can be found in Applicants' specification on p. 7 line 25; and support for claim 15 can be found in Applicants' specification on p. 6 line 15.

III. Prior Art Rejections

A. The Office Action Rejections

In paragraphs (1)-(2) of the Office Action, claims 1-3, 5-11 were rejected under 35 U.S.C. §103(a) as being unpatentable over Dwilinski et. al. U.S. Patent Application Publication No. 2006/0138431 (Dwilinski) in view of Alfano et. al. U.S. Patent Application Publication No. 2004/0135222 (Alfano)

Applicants' attorney respectfully traverses these rejections.

B. Applicants' Independent Claims

Applicants' amended independent claim 1 is directed to a method for forming a nitride semiconductor device, comprising: (a) growing one or more gallium nitride (GaN) layers on a substrate; and (b) growing one or more non-polar a-plane (Al,B,In,Ga)N layers off of a grown surface of the GaN layers to form at least one non-polar a-plane quantum well.

Applicants' amended independent claim 11 is directed to a nitride semiconductor device, comprising: (a) one or more gallium nitride (GaN) layers grown on a substrate; and (b) one or more non-polar a-plane quantum wells formed from one or more non-polar a-plane (Al,B,In,Ga)N layers grown off of a grown surface of the GaN layers.

Applicants' amended independent claim 10 is directed to the nitride semiconductor device of claim 11 created using the method of claim 1.

C. The Dwilinski Reference

Dwilinski describes a high-output type nitride light emitting device. The nitride light emitting device comprises an n-type nitride semiconductor layer, a p-type nitride semiconductor layer and an active layer therebetween, wherein the light emitting device comprises a gallium-containing nitride semiconductor layer prepared by crystallization from supercritical ammonia-containing solution in the nitride semiconductor layer.

D. The Alfano Reference

Alfano describes the design and operation of a p-i-n device, operating in a sequential resonant tunneling condition for use as a photodetector and an optically pumped emitter. The device contains III-nitride multiple-quantum-well (MQW) layers grown between a III-nitride p-n junction. Transparent ohmic contacts are made on both p and n sides. The device operates under a certain electrical bias that makes the energy level of the first excitation state in each well layer correspond with the energy level of the ground state in the adjoining well layer. The device works as a high-efficiency and high-speed photodetector with photo-generated carriers transported through the active MQW region by sequential resonant tunneling. In a sequential resonant tunneling condition, the device also works as an optically pumped infrared emitter that emits infrared photons with energy equal to the energy difference between the first excitation state and the ground state in the MQWs.

E. Applicants' Invention is Patentable Over the References

Applicants' attorney respectfully submits that the claims are patentable over the references. Specifically, Applicants' claims recite limitations not shown in the references, taken individually or in combination.

The Office Action, on the other hand, asserts the following:

> Regarding claim 1, Dwilinski teach the method for forming a nitride semiconductor device, comprising: (a) growing one or more gallium nitride (GaN) layers on a substrate (claim 10, pg. 5/ pp. 0059, pg. 10/pps. 0108-

0111); and (b) growing one or more non-polar (Al,B,In,Ga)N layers on the GaN layers (pg. 2/pp. 0016) to form at least one quantum well. It is noted that Dwilinski do not teach growing one or more nonpolar (Al,B,In,Ga)N layers on the GaN layers forming at least one the quantum well ranging in width from approximately 20 A to approximately 70 A.

However, Alfano teach (e.g. fig. 2, see also pg. 2/pp. 0017 and pg. 3/pp. 0037, on polarization effects see pg. 4/pp. 0052 and claim 19) the method for forming a nitride semiconductor device, comprising: growing one or more non-polar (Al,B,In,Ga)N layers on the GaN layers forming at least one the quantum well ranging in width from approximately 20 A to approximately 70 A for the same benefit of improving the performance of state-of-the-art optoelectronic and electronic devices by making quantum structures not influenced by polarization-induced electric fields.

Therefore, it would have been obvious to one of ordinary skill in the art at the time the invention was made to have the method for forming a nitride semiconductor device above, as disclosed by Dwilinski, comprising: growing one or more non-polar (Al,B,In,Ga)N layers on the GaN layers forming at least one the quantum well ranging in width from approximately 20 A to approximately 70 A as disclosed by Alfano for the same benefit of improving the performance of state-of-the-art optoelectronic and electronic devices by making quantum structures not influenced by polarization-induced electric fields.

Applicants' attorney respectfully disagrees, in view of the amended independent claims.

Consider, for example, the portions of Dwilinski cited by the Office Action, which are set forth below:

Dwilinski: Claim 10

10. The light emitting device structure according to claim 8, wherein said active layer is a quantum well layer structure comprising at least one of InGaN well layer or InAlGaN well layer.

Dwilinski: Paragraph [0016]

[0016] According to the present invention, a nitride bulk single crystal shown in Drawings can be prepared by applying the AMMONO method, therefore A-plane or M-plane which is parallel to C-axis of hexagonal structure for an epitaxial growth can be obtained. (FIG. 9) In the present invention, an epitaxial growth required by a device structure can be carried out in case that the plane has the area of 100 mm.sup.2. A-plane and M-plane are non-polar, unlike C-plane. In case that A-plane or M-plane of the gallium-containing nitride is used as a plane for depositing of layers, there can be obtained a laser device having no cause of the deterioration of the performance such as the red shift of light emitting, recombination degradation and increase of the threshold current. According to the present invention, when the nitride semiconductor laser device is grown on A-plane of the GaN substrate prepared by crystallization from supercritical ammonia-containing solution, the active layer of the laser device is

not subject to the polarization effect. In such a case, the light emitting face of the resonator will be M-plane, on which M-plane end face film can be formed and thus cleavage is easily performed. In case that the nitride semiconductor laser device is grown on M-plane of the GaN substrate prepared by crystallization from supercritical ammonia-containing solution, the active layer is not subject to the polarization effect and A-plane end face film being non-polar can be obtained on the light emitting face of the resonator.

Dwilinski: Paragraph [0059]

[0059] The schematic cross-sectional view of the semiconductor laser according to the present invention is shown in FIG. 1. On the substrate 1 for growth, the n-type nitride semiconductor layer 2 and the p-type nitride semiconductor layer 4 are formed. Between them there is the active layer 3 of a single quantum well or a multi quantum well structure in the form of an In-containing nitride semiconductor. This results in the laser device having a good light emitting efficiency at the wavelength region between near-ultraviolet and green visible light (from 370 nm to 550 nm). The n-type nitride semiconductor layer 2 is composed of an n-type contact layer 21, a InGaN crack-preventing layer 22, an n-type AlGaN clad layer 23 and an n-type GaN optical guide layer 24. The n-type contact layer 21 and the crack-preventing layer 22 can be omitted. The p-type nitride semiconductor layer 4 is composed of a cap layer 41, a p-type AlGaN optical guide layer 42, a p-type AlGaN clad layer 43 and a p-type GaN contact layer 44. According to the present invention, gallium-containing nitride semiconductor layer prepared by the crystallization from supercritical ammonia-containing solution can be used in the n-type nitride semiconductor layer 2 or p-type nitride semiconductor layer 4. The substrate 1 is comprised with a bulk single crystal and the dislocation thereof is remarkably low, i.e. about 10.sup.4/cm.sup.2. Therefore, the n-type contact layer 21 can be formed without ELO layer for decreasing dislocation, AlGaN layer for decreasing the pits or buffer layer. The substrate is a conductive substrate and n-type electrode is formed below the substrate so that the p-type electrode and the n-type electrode compose a face-type electrodes structure. In the above embodiment, the resonator of the semiconductor laser device is composed of the active layer 3, the p-type optical guide layer 24, n-type optical guide layer 42 and the cap layer 41.

Dwilinski: Paragraphs [0108]-[0111]

[0108] As described above, since the nitride semiconductor light emitting device according to the present invention comprises a gallium-containing nitride semiconductor layer prepared by crystallization from supercritical ammonia-containing solution, the crystalline quality can be recovered, while otherwise it would be degraded after forming the layer of quaternary or ternary compound. As the result there can be provided a laser device which is excellent in the lifetime property and current resistant property.

[0109] **Moreover, non-polar nitride A-plane or non-polar nitride M-plane is cut out from the bulk single crystal, the substrate for growth is prepared in this way, and the laser device can be formed on the A-plane or**

M-plane as an epitaxial growth face. Thus, there can be obtained the laser device wherein the active layer is not influenced by the polarization and there is no cause of the deterioration of the performance such as the red shift of light emitting, recombination degradation and increase of the threshold current.

[0110] Furthermore, in case that the current confinement layer is formed at a lower temperature, the laser device can be obtained without the device degradation, and the process for forming the ridge can be omitted.

[0111] Moreover, the nitride layer can be formed in the form of single crystal at low temperature, so that the active In-containing layer is not influenced by degradation or damaged. Therefore the function and lifetime of the device can be improved.

In Dwilinski, the GaN is grown using the AMMONO method, and then subsequently cut so that non-polar layers may be grown off of the cut surface of the GaN, not off of a grown surface of GaN layers, as recited in Applicants' amended independent claims. Specifically, the growth of non-polar layers from the cut surface of the GaN in Dwilinski does not teach or suggest the limitations of Applicants' independent claims directed to growing non-polar a-plane (Al,B,In,Ga)N layers off of a grown surface of the GaN layers to form non-polar a-plane quantum wells.

Moreover, these deficiencies of Dwilinski are not overcome by Alfano. Consider, for example, the portions of Alfano cited by the Office Action, which are set forth below:

Alfano: FIG. 2

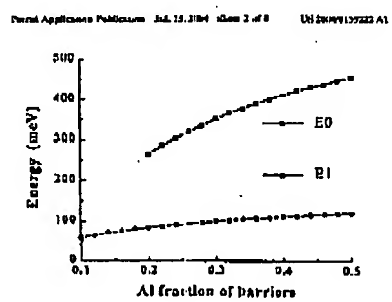

FIG. 2

Alfano: Paragraph [0017]

[0017] Photodetectors and emitters according to the present invention are based on III-nitride multiple quantum wells. The devices have a p-n junction with III-nitride MQW layers sandwiched between p type semiconductor and n type semiconductor III-nitride layers. Ohmic contacts are provided for the surfaces of both p type and n type semiconductor layers. Structure parameters of the device are adjustable to achieve desired features of the photodetector. The photodetector operates in a certain biased condition where photogenerated carriers are transported through the MQW layers by sequential resonant tunneling. The device can also operate as an optically pumped infrared emitter which amplifies input optical signal by a factor of M, where M is equal to or smaller than the number of the quantum wells. These devices have high transport efficiency, high absorption efficiency, high quantum efficiency and high response speed. Devices according to the present invention incorporate undoped or lightly doped III-nitride MQW layers embedded in p-type and n-type III-nitride semiconductor layers. By introducing these multiple quantum well layers as an active region, the performance of photodetectors and emitters is greatly improved. Ohmic contacts are made to the front and back surfaces of the p and n semiconductor layers. The mole fractions of group III elements in the nitride compounds used in the device are adjustable from 0 to 1 according to desired wavelength cutoffs of from 630 nm (InN) to 200 nm (AlN). The device operates in an electrically biased condition, where sequential resonant tunneling of photogenerated carriers occurs in the MQW region. In this condition, both radiative and non-radiative carrier recombination are effectively decreased and high efficient photon detection and emission is obtained.

Alfano: Paragraph [0037]

[0037] As a reference, FIG. 2 presents the calculated energy positions of the ground state and the first excited state of electrons in the conduction band as a function of aluminum mole fraction of barriers for a GaN/AlGaN MQW structure with well thickness of 4 nm. The values on the ordinate scale represent the energy distance from the conduction minimum of GaN. The MQW layers are typically undoped or doped by compensation to make them semi-insulate.

Alfano: Paragraph [0052]

[0052] There exist giant internal fields (up to 10.sup.6 V/cm) in the quantum wells based on III-nitride materials which are induced by large spontaneous and piezoelectric polarization. These fields dramatically modify optical and electrical properties of III-nitride MQW structures, as well as the performance of the designed photodetector. **To maximize the quantum efficiency and the transport efficiency of the photodetector, the growth process should make the orientation of the spontaneous polarization point to the n type layer. In this case, the internal electric fields in the quantum wells point from the p layer to the n layer.** Under the working bias, the magnitude of

these internal electric fields will be reduced. This will greatly increase absorption efficiency of the MQWs, and at the same time, keep a low dark current level.

Alfano: Claim 19

19. The device of claim 1, wherein said III-nitride multiple quantum well layers are alternatively: a) polar, with polarization extending from said p semiconductor layer to said n layer; and b) non-polar.

Alfano merely describes c-plane polar quantum wells, not the non-polar a-plane quantum wells of Applicants' amended independent claims.

As noted above, in paragraph [0052], Alfano states, in relevant part, that the growth process should make the orientation of the spontaneous polarization point to the n type layer and that, in this case, the internal electric fields in the quantum wells point from the p layer to the n layer. Since Alfano describes growth of quantum wells such that a spontaneous polarization and internal electric field points from the p-layer to the n-layer, it is inherent the polar axis of Alfano's layers cannot be in a growth plane of non-polar a-plane (Al,B,In,Ga)N layers, as recited in Applicants' amended independent claims.

Moreover, while Alfano's claim 19 refers to non-polar quantum wells, there is no description in Alfano's specification of non-polar m-plane or a-plane quantum wells. Specifically, Alfano's specification does not describe growing non-polar a-plane (Al,B,In,Ga)N layers off of a growth surface of the GaN layers to form non-polar a-plane quantum wells, as recited in Applicants' amended independent claims.

Thus, Applicants' attorney submits that independent claims 1, 10 and 11 are allowable over Dwilinski in view of Alfano. Further, dependent claims 5-9 and 12-20 are submitted to be allowable over Dwilinski and Alfano in the same manner, because they are dependent on independent claim 1, respectively, and thus contain all the limitations of the independent claims. In addition, dependent claims 5-9 and 12-20 recite additional novel elements not shown by Dwilinski and Alfano.

IV. Conclusion

In view of the above, it is submitted that this application is now in good order for allowance and such allowance is respectfully solicited. Should the Examiner believe minor matters still

remain that can be resolved in a telephone interview, the Examiner is urged to call Applicants' undersigned attorney.

Respectfully submitted,

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